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Two-Dimensional Cephalometric Analysis of the Effects of Subperiosteal Palatal Soft-Tissue Expansion in Growing Cats

Philip A. Van Damme, M.D., D.M.D., Ph.D., Jaap C. Maltha, Ph.D., Anne Marie Kuijpers-Jagtman, D.M.D., Ph.D., Hans Peter M. Freihofer, M.D., D.M.D., Ph.D., and Martin A. Van't Hof, Ph.D.

Nijmegen, The Netherlands

The feasibility and possible effects of palatal soft-tissue expansion in palatal repair were studied. A prospective longitudinal animal experiment was performed in 75 growing cats assigned to 5 groups. In 31 cats, a midline defect was made, and bipedicled flaps were raised at the age of 8 weeks (simulated Langenbeck operation) in order to create palatal scars. At the age of 14 weeks, custom-made tissue expanders were inserted palatally in 61 animals. Tissue expansion was performed by weekly inflation in 33 cats (16 without and 17 with scars) for an 8-week period. The remaining 28 cats (14 without and 14 with scars) served as sham groups. A control group was formed by 14 animals (without scars and without tissue expanders). Soft-tissue gain and its effects on maxillofacial growth and development were measured in the midsagittal plane on tracings from standardized lateral radiographs. The effects of the experimental interventions were evaluated for 8 weeks after removal of the tissue expanders. Not all the cats yielded results at all time periods.

This study showed that soft-tissue expansion of palatal mucoperiosteum is feasible. The surgically induced scars did not cause significant differences between the different groups in the midsagittal plane, and the data from both expansion and sham groups could be pooled. Significant soft-tissue gain was achieved by the tissue-expansion technique. Iatrogenic side effects were significant anteroposterior growth retardation at the level of the bony palate and an increase in vertical growth of the anterior nasomaxillary height and the posterior skull height during active tissue expansion. After removal of the tissue expanders, some accelerated growth was found in the tissue expansion in the scarred tissue group, with initial correction of the abnormal growth at the cranial base level.

It is concluded that palatal soft-tissue expansion is possible in growing cats. This technique, however, impaired maxillofacial growth and development. (*Plast. Reconstr. Surg.* 99: 1960, 1997.)

The use of soft-tissue expansion for facilita ing the closure of palatal defects in cleft lip an palate is new and has seldom been reported.[1] The usual techniques for closure of oronas communications in cleft lip and palate a summarized by Millard.[4] Secondary fistulas a reported to occur as failures in 5 to 30 perce of cases after primary cleft repair.[4] Recent reported closure techniques are various locor gional pedicled mucoperiosteal flaps, such tadpole flaps,[5] buccal musculomucosal flaps buccal fat pad flaps,[7,8] different lingu flaps,[9–11] and temporal muscle and/or fasci flaps,[12,13] as well as other techniques.[14,15] The flaps do not always yield good results. For i stance, with the buccal musculomucosal fla complete closure can be achieved in 35 to 7 percent of secondary fistulas at first attemp depending on the size and site of the defects Closure generally becomes more difficult an the techniques become less reliable when mu tiple closure attempts have been made.[4,15]

There are several disadvantages to thes flaps. Some of them are two-stage procedure create a donor-site defect, and use tissue different origin, texture, and characteristics fo the repair. The techniques may result in ten porary functional disturbances. Lingual flap for example, cause temporary impairment tongue function with speech interference, an

From the Departments of Oral and Maxillofacial Surgery, Orthodontics and Oral Biology, and Medical Statistics at the University of Nijmege
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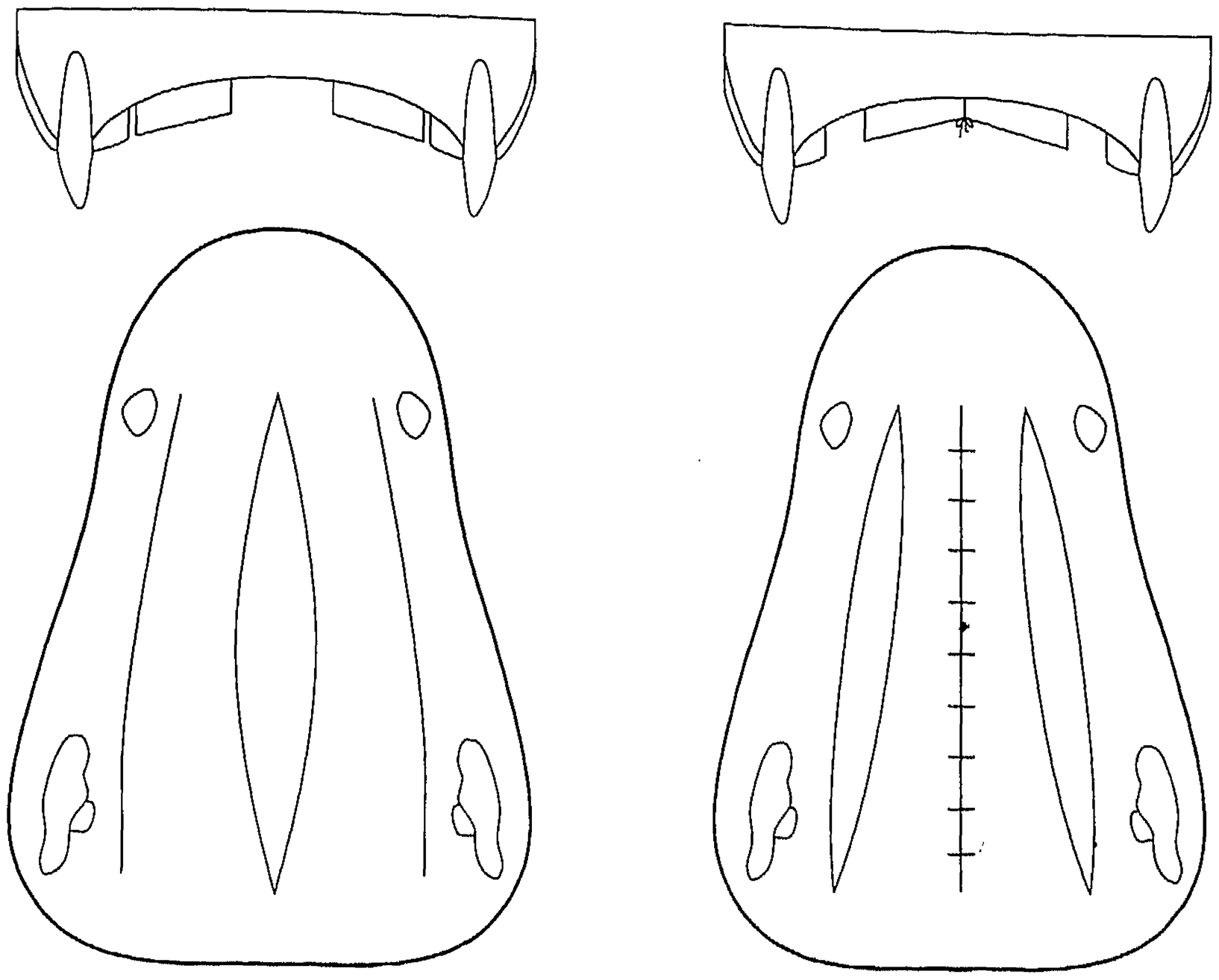

FIG. 1. Schematic drawing of modified Langenbeck operation. Excision of lenticular part of the palatal mucoperiosteum in the midline (*left*) and bilateral relaxation incisions. Elevation of the mucoperiosteum and closure of the midline defect (*right*). Three scars are created: one healed per primam in the midline and two by secondary intention laterally on both sides.

sometimes intermaxillary fixation is needed during the healing phase.

Free microvascularized flaps, such as the radial forearm fasciocutaneous flap, are hazardous, time-consuming, and bulky and often cause donor-site morbidity and visible scars.[16,17] Also, each surgical intervention has a negative effect on subsequent growth and development of the dentomaxillofacial complex.[18–27] A reduction in the number of palatal operations and subsequent scarring is therefore a desirable goal.

Soft-tissue expansion has been used in craniomaxillofacial surgery since 1981.[28] More recently, the use of a soft-tissue expander for closure of palatal fistulas has been advocated.[1,2] Few studies have reported on the effects of tissue expansion on growth and development in growing individuals.[29,30] In order to quantify the positive and/or negative effects of subperiosteal palatal soft-tissue expansion on the anteroposterior and vertical growth of the maxilla, a prospective longitudinal animal experiment was performed and maxillary growth was evaluated radiographically.

The present study evaluates the feasibility and effects of tissue expansion on the palatal mucoperiosteum of growing cats with and without preexisting scars.

MATERIALS AND METHODS

Seventy-five domestic tomcat kittens aged 8 weeks were assigned to five groups: group I, tissue expansion group ($n = 16$); group II, sham group ($n = 14$); group III, tissue expansion in scar tissue group ($n = 17$); group IV, sham in scar tissue group ($n = 14$); and group V, control group ($n = 14$). The animals were housed under normal laboratory conditions in the Central Animal Laboratory, University of Nijmegen, and received a diet consisting of granules, canned meat, and drinking water ad libitum. The cats were weighed every week and prior to any intervention.

All interventions were performed under standard general anesthesia, induced by 30 mg/kg ketamine HCl intramuscularly (Nimatek 100 mg/ml, A.U.V. Cuijk, The Netherlands) with 0.5 ml atropine intramuscularly (atropine sulfate 0.5 mg/ml) and maintained after endotracheal intubation with a mixture of 0_2 (1 liter/min), N_20 (2 liters/min), and 0.5% to 4.0% enflurane (Ethrane, Abbott B.V., Amstelveen, The Netherlands).

A simulated Langenbeck operation was performed under sterile conditions in groups III and IV at the age of 8 weeks. For this purpose, the oral cavity and perioral region were disinfected with Betadine solution (povidone-iodine 10%, Dagra-Pharma B.V., Diemen, The Netherlands). Thereafter, a standardized lenticular soft-tissue defect was created in the median region of the palate by excising a mucoperiosteal flap (Fig. 1). This flap extended from just behind the incisive papilla to the caudal margin of the hard palate. The maximum width of the flap was one-third the transverse distance between the deciduous first molars. On both sides, relaxation incisions were made adjacent to the posterior teeth. The mucoperiosteum was elevated, and the soft-tissue defect was closed in the midline in one layer with 5-0 Vicryl (Ethicon, Johnson & Johnson Company, Amersfoort, The Netherlands), leaving two areas of denuded bone adjacent to the posterior teeth to heal by secondary intention. Healing was allowed for 6 weeks until the age of 14 weeks.

At 14 weeks of age, custom-made hemispherical soft-tissue expanders (CUI, Inamed B.V., Breda, The Netherlands) were inserted in groups I through IV (Fig. 2). The tissue expanders were made of silicone and had a diameter of 12 mm at their base and a filling volume of 1 ml.[31,32] The length of the external filling tube, with an incorporated self-sealing port, was 15 mm.

To introduce the expander, a standardized paramarginal palatal incision from left to right upper canine was made to create a submucoperiosteal pocket of approximately 15 × 15 mm by elevation of the mucoperiosteum. Both anterior palatal neurovascular bundles were coagulated, while the posterior palatal neurovascular bundles were spared. A 2-mm incision was made on the buccal side, between the canine and the first deciduous molar, and the gingiva and mucoperiosteum were tunneled to allow the external filling tube through (Fig. 3). The palatal incision was closed with 5-0 Vicryl sutures.

Perioperative antibiotics were administered: preoperatively, 0.5 ml Albipen 15% intramuscularly (ampicillin anhydrate 150 mg/ml, Gist-Brocades N.V., Delft, The Netherlands), and postoperatively, on days 1 and 3, 1.0 ml Albipen L.A. intramuscularly (ampicillin anhydrate 100 mg/ml). The wounds were inspected daily for the first week after surgery or, when indicated, for a longer period. Healing was allowed for 2 weeks until the age of 16 weeks.

All inserted expanders were filled initially with 0.1 ml of a radiopaque solution (Angiografin, meglumine amidotrizoate 650 mg/ml, 306 mg I/ml, Schering A.G., Berlin, Germany). Thereafter, approximately 0.1 ml Angiografin was added weekly to each tissue expander in groups I and III, by means of a blunt 22-gauge needle, until the age of 24 weeks. In groups II and IV, no additional filling of the tissue expanders was performed after the initial filling. At 24 weeks the tissue expanders and the tissue surplus were removed surgically, and the wound was closed with 5-0 Vicryl sutures. The animals were monitored for another 8 weeks according to the same regimen of recording of data. No surgery was performed in group V, but the animals were monitored and assessed in the same manner as the operated groups.

Radiographs were taken every 2 weeks under standardized conditions in a specially designed

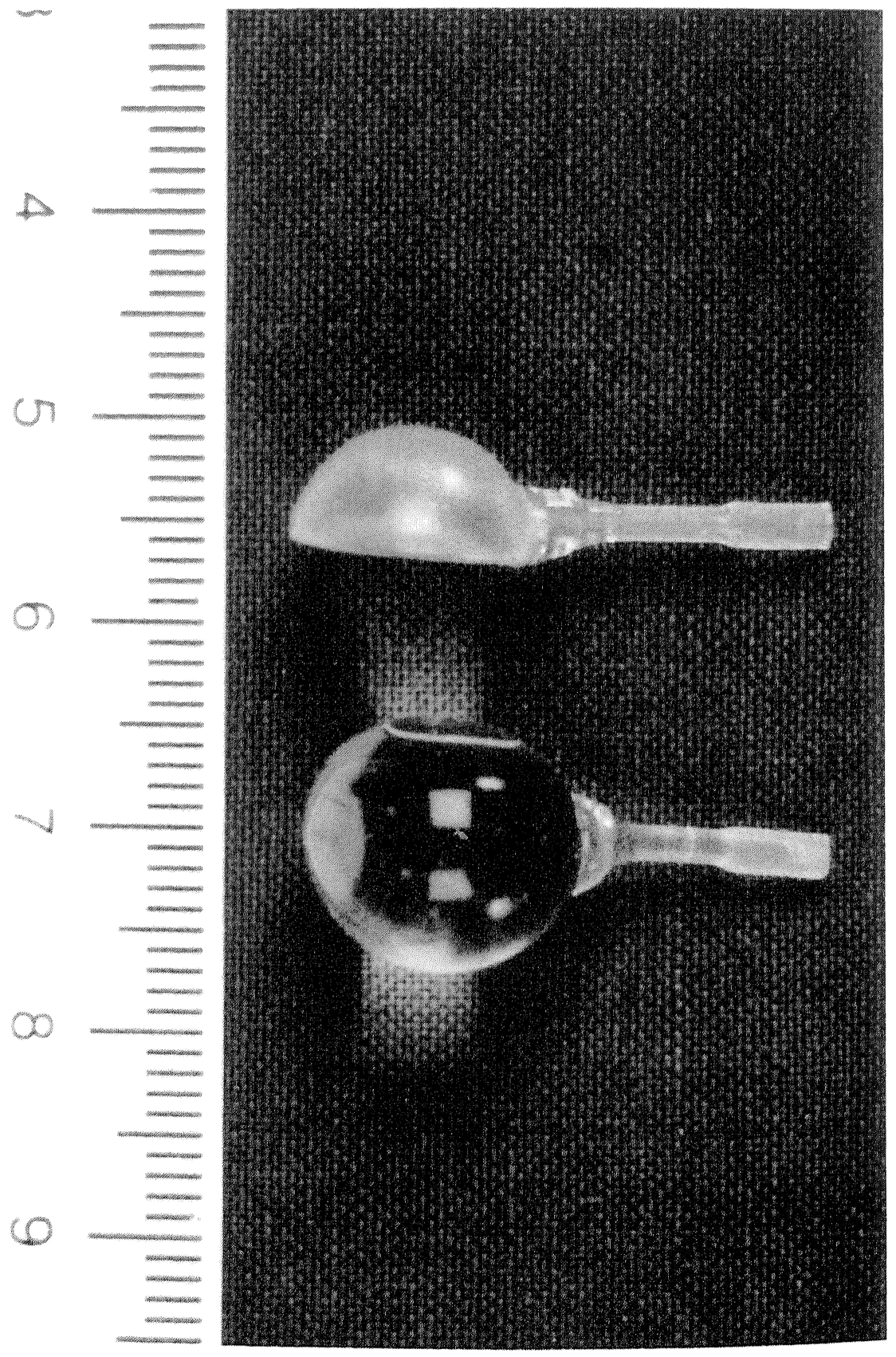

FIG. 2. Lateral view of custom-made hemispheric tissue expander with self-sealing filling port. Base diameter in empty state 12.0 mm, height 6.0 mm, filled height 12.0 mm.

FIG. 3. Lateral view with tissue expander in situ and external filling tube tunneled between canine and first deciduous molar.

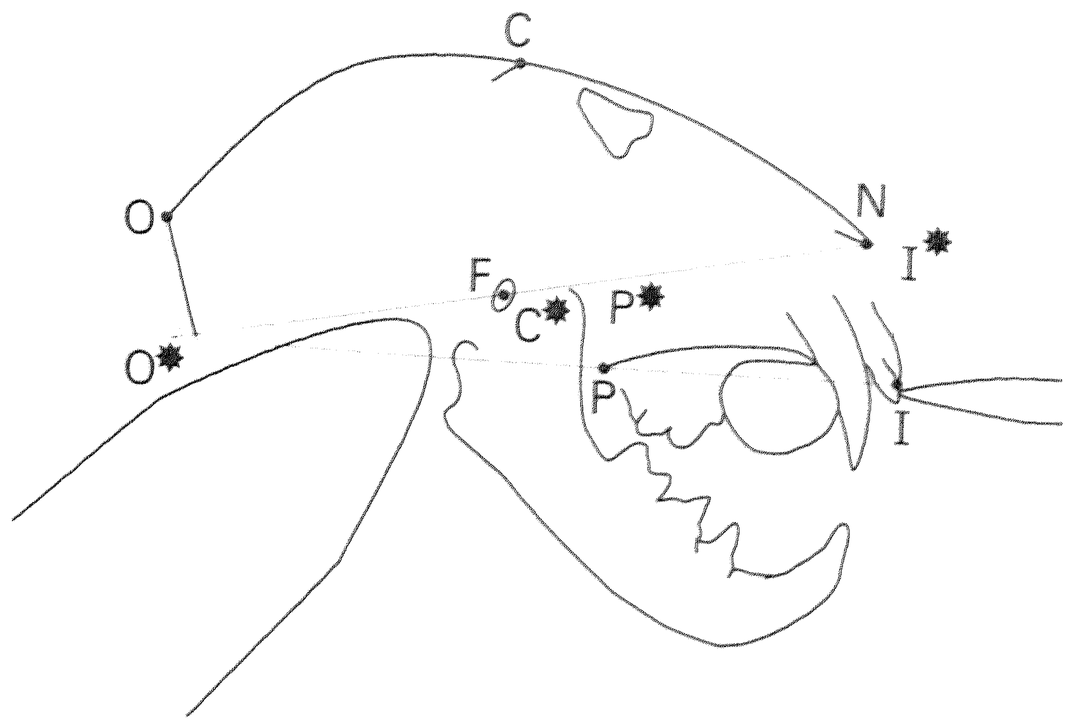

FIG. 4. Schematic drawing of lateral cephalogram with points indicated. For definition of the points, see text.

cephalostat.[33] The animals were fixed in the cephalostat with two ear rods and a pin in the midsagittal plane. Kodak diagnostic film Min-r (Eastman Kodak Company, Rochester, N.Y.) was used. A Philips Practix x-ray machine (Philips, The Hague, The Netherlands) was used and set at 20 mA and 100 kV with an exposure time of 10 seconds. The focus-film distance was 4.5 m, and the object-film distance was 9 cm.

Thirteen cats had to be excluded from the study as a result of technical failures. Sixty-two cats were followed until the age of 20 weeks, and 52 cats were followed for the entire inflation period up to 24 weeks. Forty animals were studied during the 8 weeks after removal of the tissue expander.

All radiographs were examined independently by two investigators. The following anatomic reference points were identified and marked on the tracings (Fig. 4): *P*, most posterior point of the bony palate; *F*, center of the optic foramen; *O*, most posterior point of the occiput; *C*, intersection of the coronal suture and the external cortical bone plate; *N*, most anterior point of the nasal bone; and *I*, intersection of the labial contour of the central incisor and the alveolar bone. The contour of the tissue expander also was traced.

The points and structures were digitized independently by both observers using an *X-Y* digitizing tablet (Hitachi HDG-1111B, Manudax Nederland B.V., The Netherlands),[34] which was connected to a computer (IBM-PC PS 2, Model 70 386) with a mathematical coprocessor. The projections of the points *P*, *O*, *C*, and *I* on the line *NF* were denoted *P**, *O**, *C**, and *I**.

The following distances and angles were calculated (see Fig. 4): *PI* direct distance, *PI* indirect distance (along the oral outline of the tissue expander), *NF*, *I*F*, *P*F*, *O*F*, *II**, *PP**, *CC**, *OO**, and angle *NF/PI*.

The error of the cephalometric procedures was determined by measurements on repeated exposures of 15 cats of different ages. The animals were removed and then replaced in the cephalostat between the exposures.

Means and standard deviations were calculated for the increments of all variables in all groups. Increments were defined as differences between two time periods. Comparison between the groups was carried out by one-way analysis of variance (ANOVA) and analysis of covariance, and if significant differences between groups were found, Tukey's multiple-comparisons test was used for evaluation of these differences.

Analysis was performed for the period from 14 to 20 weeks of age for 62 cats and for the period from 14 to 24 weeks of age for 52 cats. Also, a period of 8 weeks after removal of the tissue expanders was evaluated in 40 animals. Intraobserver and interobserver variability tests were performed to check the accuracy and reproducibility of the procedures.

RESULTS

Error Analysis

The total error of the cephalometric procedure is composed of an error in the positioning of the animals in the cephalostat, the tracing procedure, including the definition of points and structures on the lateral cephalograms, and the measuring procedure. The duplicate exposures at different ages showed a

TABLE I

Increments 14 to 20 Weeks: Initial 6 Weeks after Insertion of Tissue Expander

Variable	Pooled Groups (n = 62) I and III TE (n = 26) Mean	Pooled Groups (n = 62) II and IV SH (n = 22) Mean	V CO (n = 14) Mean	Pooled SD	Intergroup Difference ($p < 0.05$)
1 *PI* direct	1.79	1.93	2.32	0.49	TE < CO
2 *PI* indirect	7.23	2.25	2.32	1.39	TE > SH, CO
3 *NF*	3.07	3.07	2.94	0.38	
4 *I*F*	2.77	3.07	3.27	0.46	TE < CO
5 *P*F*	1.08	1.20	0.99	0.38	
6 *O*F*	1.23	1.19	1.15	0.43	
7 *II**	1.38	1.06	1.17	0.34	TE > SH
8 *PP**	0.68	0.60	0.74	0.32	
9 *CC**	0.32	0.38	0.17	0.41	
10 *OO**	1.02	0.81	0.71	0.69	
11 <*NF/PI*	0.69	0.17	0.05	0.79	TE > CO

Note: Values in mm resp. degrees per month; increments = differences between two time periods.

mean total error of 0.23 mm. The angle *NF/PI* showed a mean total error of 0.92 degrees. Based on these results, the accuracy and reproducibility of the methods were considered to be acceptable.

Effects of the Interventions

Mutual comparison of all groups by one-way ANOVA revealed no significant differences between comparable scarred and nonscarred groups for any of the parameters until removal of the expander. Additional analysis of covariance supported that scarring of the tissue itself was not decisive for the effects of tissue expansion on maxillofacial growth and development in the sagittal plane. This meant that pooling of groups I and III as well as of groups II and IV was allowed. Pooling resulted in a tissue-expansion group TE, consisting of 26 (20) cats, and a sham group SH, consisting of 22 (18) animals (Tables I and II). The pooled groups TE, SH, and CO (controls, n = 14) were mutually compared by one-way ANOVA, and significant differences, if any, were subsequently explored by Tukey's multiple-comparisons test.

The differences caused by the interventions were more pronounced for the period from 14 to 24 weeks of age than for the period from 14 to 20 weeks, indicating time-related effects.

The changes in distance *PI* direct, which are a measure of palatal growth, indicated that tissue expansion and, to a lesser extent, surgery itself slowed down the anteroposterior growth of the maxilla (Fig. 5). The distance *PI* indirect increased, as expected, significantly faster in the TE group than in the others (Fig. 6). Measurements along the "cranial base," defined as the line *NF,* indicated a relative posterior change in the position of point *I** due to the tissue expansion, as expressed by the distance *I*F.* The vertical dimensions in the anterior

TABLE II

Increments 14 to 24 Weeks: Initial 10 Weeks after Insertion of Tissue Expander

Variable	Pooled Groups (n = 52) I and III TE (n = 20) Mean	Pooled Groups (n = 52) II and IV SH (n = 18) Mean	V CO(n = 14) Mean	Pooled SD	Intergroup Difference ($p < 0.05$)
1 *PI* direct	1.52	1.65	1.96	0.32	TE, SH < CO
2 *PI* indirect	5.62	1.80	1.96	1.18	TE > SH, CO
3 *NF*	2.53	2.64	2.57	0.32	
4 *I*F*	2.30	2.71	2.85	0.31	TE < CO, SH
5 *P*F*	0.86	1.07	0.92	0.26	
6 *O*F*	1.06	1.12	1.26	0.30	
7 *II**	1.18	0.84	0.92	0.24	TE > SH, CO
8 *PP**	0.59	0.63	0.61	0.23	
9 *CC**	0.21	0.25	0.15	0.22	
10 *OO**	0.97	0.73	0.63	0.38	TE > CO
11 <*NF/PI*	0.55	−0.16	−0.04	0.50	TE > SH, CO

Note: Values in mm resp. degrees per month; increments = differences between two time periods.

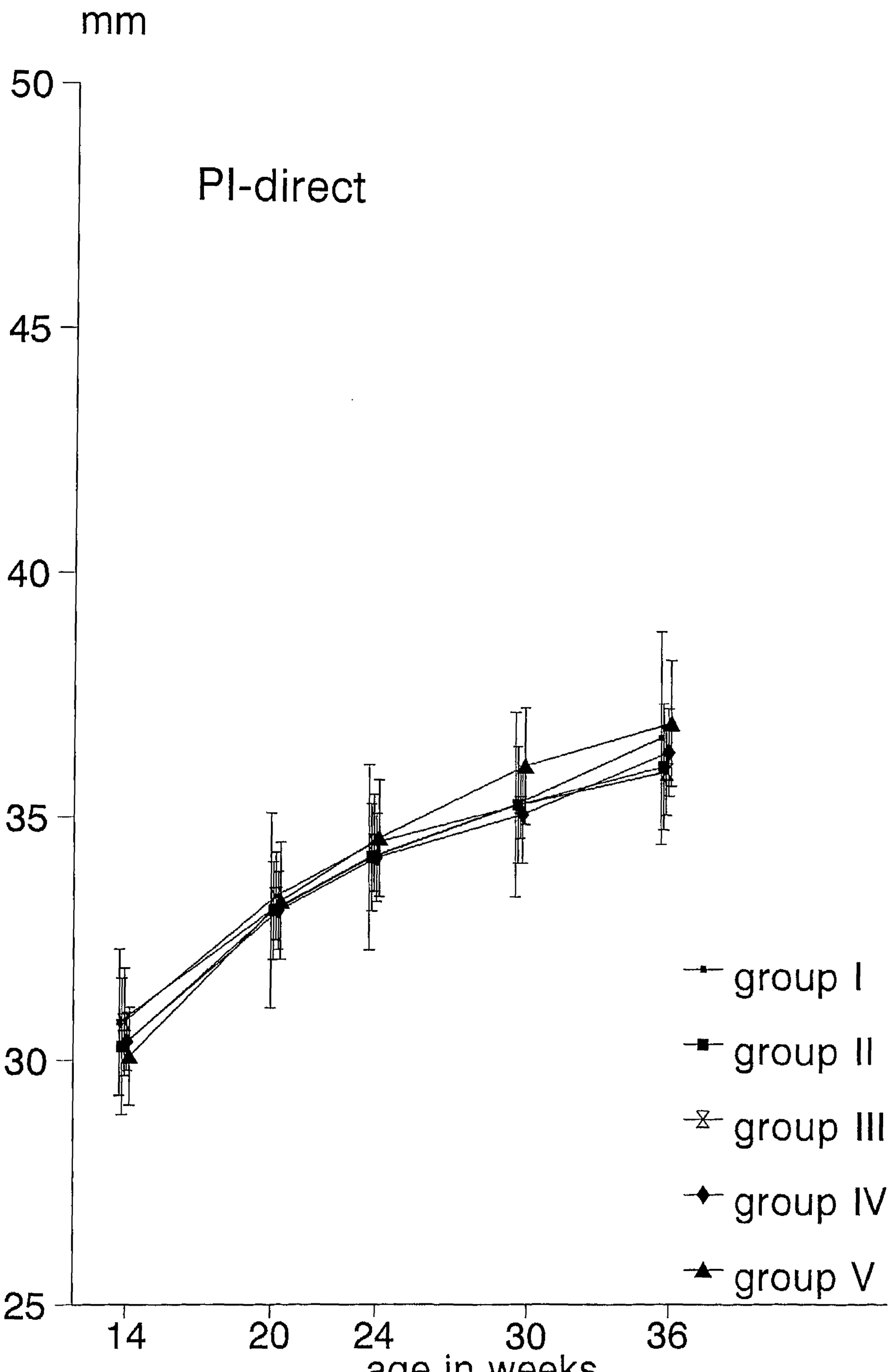

FIG. 5. Plotted diagram of mean values of *PI* direct versus time. Time is on the horizontal axis and *PI* direct on the vertical axis.

region, as represented by the distance *II**, increased faster in the TE group than in the SH or CO groups (Fig. 7). This also resulted in a significantly larger increase in the angle *NF/PI* in the TE group than in the SH and CO groups after 24 weeks.

The distance *OO**, which is an indication of the posterior skull height, appeared to increase faster in the TE group than in the CO group when the period up to 24 weeks of age was considered.

The increments in the first 4 weeks after removal of the tissue expanders showed three significant differences, two of which seemed to

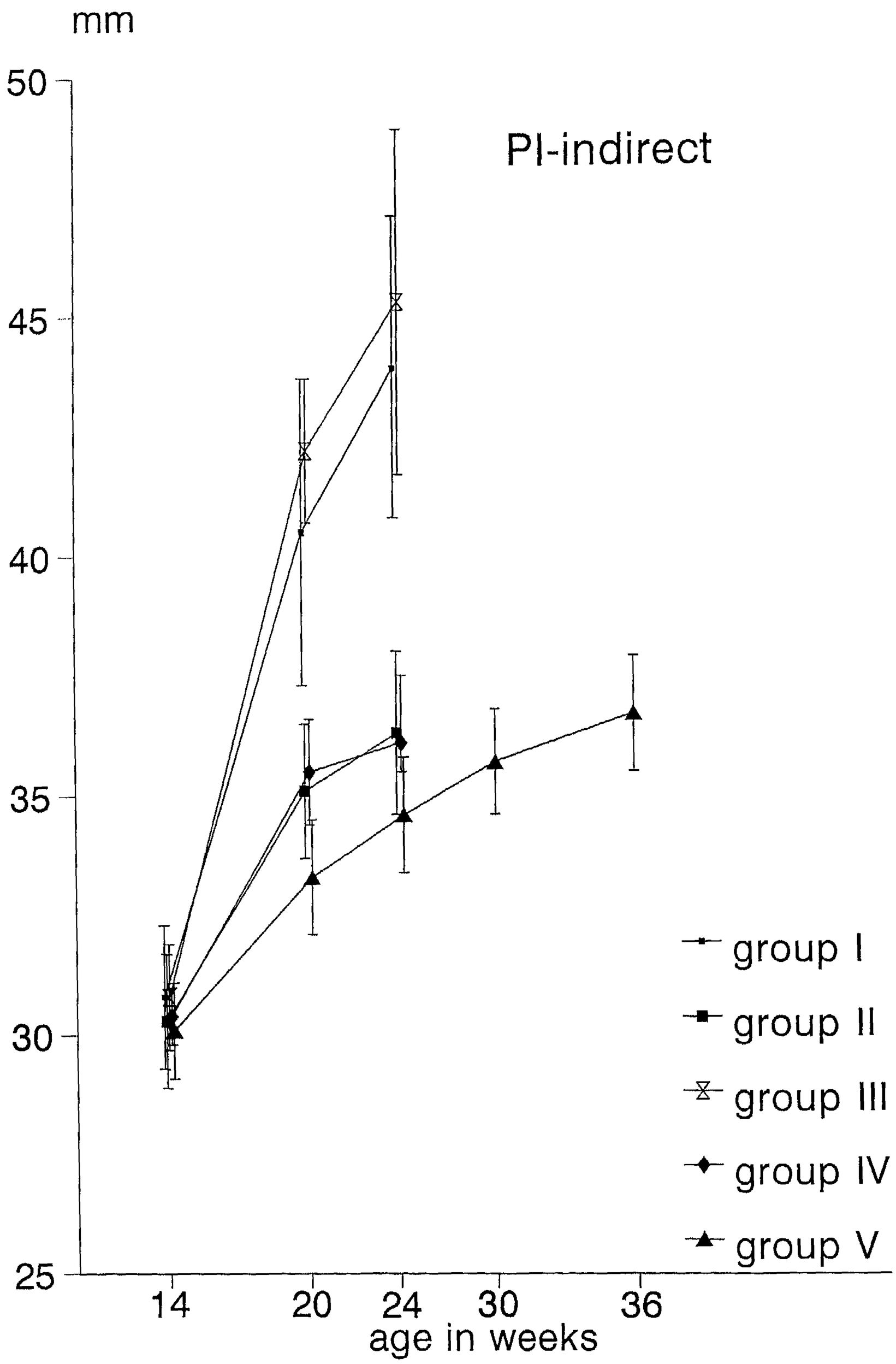

FIG. 6. Plotted diagram of mean values of *PI* indirect versus time. Time is on the horizontal axis and *PI* indirect on the vertical axis.

be temporary and one (*P*F*) persistent (Tables III and IV).

The measurements in the period from 4 to 8 weeks after removal of the tissue expanders revealed some significant differences in the increase of distances related to point *F* (see Table IV). The increase in the distances anterior to point *F* (*NF*, *I*F*, and *P*F*) was significantly larger in group III than in the unscarred groups. The distances *NF* and *P*F* in group I increased significantly less than in the scarred groups III and IV. Only two parameters of the control group showed significant differences with any of the experimental data: *P*F* in-

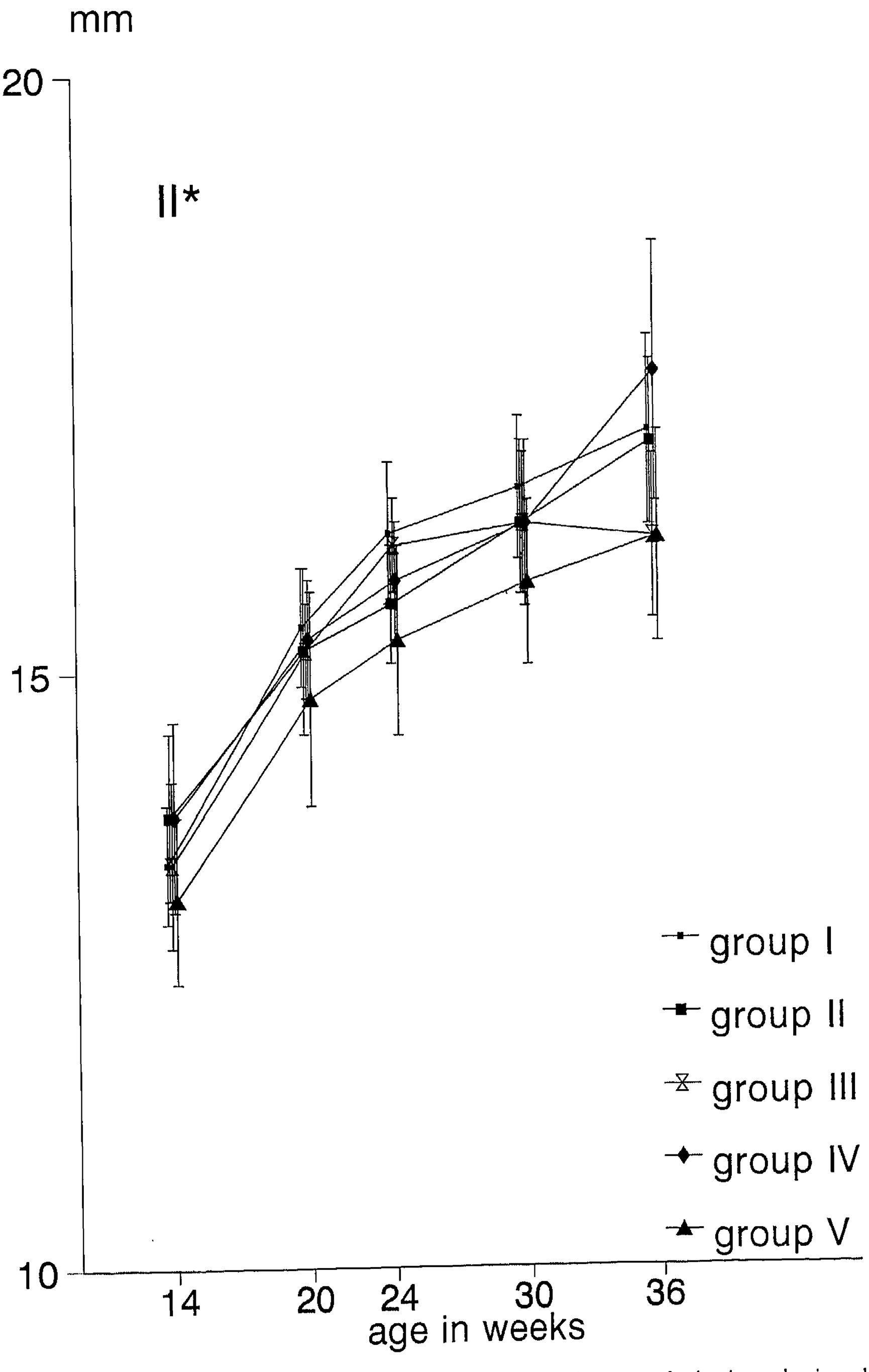

FIG. 7. Plotted diagram of mean values of *II** versus time. Time is on the horizontal axis and *II** on the vertical axis.

creased more in the control group than in group I, and *I*F* increased less in the control group than in group III.

In the 8 weeks after removal of the tissue expander, group III was significantly different from the other groups for the parameters *NF*, *I*F*, and *P*F*, with significant increases in group III (Table V). Furthermore, *P*F* increased significantly more in group IV compared with group I.

DISCUSSION

This study has tried to evaluate the effects and further possibilities of tissue expansion of

TABLE III
Increments First 4 Weeks after Removal of Tissue Expander

Variable	Group (n = 40) I TEXP (n = 9) Mean	II SEXP (n = 7) Mean	III TSCA (n = 6) Mean	IV SSCA (n = 6) Mean	V CONT (n = 12) Mean	Pooled SD	Intergroup Difference ($p < 0.05$)
1 *PI* direct	0.89	0.83	0.79	0.71	0.97	0.28	
2 *PI* indirect	0.89	0.83	0.79	0.71	0.97	0.28	
3 *NF*	1.16	1.01	1.39	1.00	1.20	0.44	
4 *I*F*	1.24	1.41	1.78	1.09	1.48	0.37	IV < V
5 *P*F*	0.39	0.54	0.97	0.43	0.49	0.35	I < III
6 *O*F*	0.45	1.07	0.58	0.54	0.94	0.41	I < II
7 *II**	0.43	−0.00	0.42	0.17	0.39	0.49	
8 *PP**	0.20	0.14	0.50	−0.16	0.46	0.47	
9 *CC**	0.10	0.21	0.05	−0.13	−0.02	0.50	
10 *OO**	0.99	0.36	0.44	0.27	0.11	0.69	
11 <*NF/PI*	0.13	−0.48	−0.36	0.32	−0.37	1.15	

Note: Values in mm resp. degrees per month; increments = differences between two time periods.

the palatal mucoperiosteum in growing cats with and without preexisting scars. Since extrapolation to the human clinical situation is important, an animal model was chosen with a deciduous and permanent dentition. Beagle dogs, although apparently suitable for study, were not selected for this experiment because of their non-human-like palatal anatomy.[24,33] The morphology of the palate of the domestic cat appears to be suitable for comparisons with humans.[20–22]

It is still impossible to breed nonrodent mammals with identical congenital clefts.[35] Creating an artificial palatal cleft by surgery has major negative effects on growth and development of the dentomaxillary complex.[19] This means that no reliable starting point exists after surgery.

To be able to check the validity of the soft-tissue expansion technique in scarred tissue, as is usually present in cleft lip and palate situations, a simulated Langenbeck operation[36] was performed. The effects of this surgical intervention are well documented for dogs[23–27] and assumed to be more or less the same for cats.[20–22] The most prominent growth disturbances due to this type of operation were found in the transverse dental arch measures, which are beyond the scope of the present study. Only minor temporary changes in the anteroposterior dimensions were found.[25] Also, the present study revealed no significant effect of the simulated Langenbeck operation on any of the parameters in the sagittal plane during tissue expansion. As a consequence, the Langenbeck and non-Langenbeck groups were pooled.

Palatal soft-tissue expansion may interfere with food intake by mechanical hindrance and expansion-related discomfort. This is reported to occur during and shortly after inflation.[37] To examine this possible effect on nutrition,

TABLE IV
Increments Last 4 Weeks after Removal of Tissue Expander

Variable	Group (n = 40) I TEXP (n = 9) Mean	II SEXP (n = 7) Mean	III TSCA (n = 6) Mean	IV SSCA (n = 6) Mean	V CONT (n = 12) Mean	Pooled SD	Intergroup Difference ($p < 0.05$)
1 *PI* direct	1.11	0.70	0.68	0.50	0.64	0.24	
2 *PI* indirect	1.11	0.70	0.68	0.50	0.64	0.24	
3 *NF*	0.44	0.68	1.26	1.03	0.82	0.35	I, II < III; I < IV
4 *I*F*	0.79	0.65	1.48	0.96	1.02	0.30	I, II, IV, V < III
5 *P*F*	−0.01	0.02	0.68	0.51	0.41	0.30	I, II < III, IV; I < V
6 *O*F*	0.75	0.36	1.04	0.72	0.52	0.43	
7 *II**	0.25	0.71	−0.08	0.67	0.29	0.77	
8 *PP**	0.34	0.29	0.49	0.40	0.07	0.55	
9 *CC**	−0.07	0.04	0.01	−0.07	0.30	0.62	
10 *OO**	0.07	0.83	−0.17	0.58	0.83	1.04	
11 <*NF/PI*	−0.41	0.47	−1.15	0.29	0.18	1.39	

Note: Values in mm resp. degrees per month; increments = differences between two time periods.

TABLE V
Increments 8 Weeks after Removal of Tissue Expander

Variable	Group (n = 40) I TEXP (n = 9) Mean	II SEXP (n = 7) Mean	III TSCA (n = 6) Mean	IV SSCA (n = 6) Mean	V CONT (n = 12) Mean	Pooled SD	Intergroup Difference ($p < 0.05$)
1 *PI* direct	0.83	0.77	0.74	0.61	0.81	0.15	
2 *PI* indirect	0.83	0.77	0.74	0.61	0.81	0.15	
3 *NF*	0.81	0.85	1.33	1.02	1.02	0.19	I, II, IV, V < III
4 *I*F*	1.02	1.04	1.64	1.03	1.25	0.23	I, II, IV, V < III
5 *P*F*	0.19	0.28	0.83	0.47	0.45	0.18	I, II, IV, V < III; I < IV
6 *O*F*	0.60	0.72	0.81	0.63	0.74	0.23	
7 *II**	0.34	0.35	0.17	0.42	0.34	0.31	
8 *PP**	0.27	0.21	0.49	0.12	0.27	0.26	
9 *CC**	0.01	0.13	0.03	0.03	0.14	0.26	
10 *OO**	0.49	0.60	0.14	0.43	0.47	0.43	
11 *<NF/PI*	−0.14	−0.00	−0.76	0.31	−0.10	0.64	

Note: Values in mm resp. degrees per month; increments = differences between two time periods.

weight gain was monitored and recorded carefully on a weekly basis. No decrease or abnormal weight changes were found.

Complications of soft-tissue expansion in the head and neck area are well established.[3,28,38,39] Complication rates vary from 0 to 69 percent depending on surgeon, time, technique, and anatomic site. Most authors reported high complication rates early in their experience, with a subsequent decrease. In a pilot study, the various techniques were practiced in order to accrue enough experience to start the experimental study. Complication rates in the present study varied from 20 to 25 percent, depending on the group and the initial filling volume of the expander. Erosions, necrosis of the soft tissues, leakage, and extrusions of the expander were the most frequent complications and were seen mainly in the scarred tissue groups.

In both groups with inflated tissue expanders, a considerable increase in the palatal soft tissue was found, as was expected. This proves that tissue expansion of the intraoral mucoperiosteum is possible and that it yields at least a temporary tissue gain. The effects of the experimental intervention became more prominent with increasing time after the intervention.

Tissue expansion and to a lesser extent palatal surgery itself, however, caused some adverse side effects on the growth of bony structures. Palatal growth was reduced in the anteroposterior direction, and the anterior nasomaxillary height was increased. This is possibly due to the fact that with the increasing volume of the tissue expander, the animals were less able to close their mouths. This might result in an overeruption of the maxillary incisors. Furthermore, the increased intraoral mucoperiosteal tension caused by the tissue expander may cause palatal tipping of the incisors and a restraining effect on anteroposterior palatal growth.

The changes in the cranial base region indicated changing proportions of measuring points relative to point *F*, the optical foramen. Tissue expansion resulted in an increase in the height of the skull in the occipital region. This phenomenon was quite unexpected, and we can forward no explanation for it.

In the first weeks after removal of the tissue expanders, nearly all increments in the experimental groups returned to the normal, control values. Later on, some significant differences between the groups developed. All these differences were found in the cranial base region and not in the parameters involved in palatal length and nasomaxillary height. This means that although the growth rates in that area soon after removal of the tissue expander returned to normal, it still is questionable whether real catch-up growth takes place beyond the period of 8 weeks after removal of the tissue expander. These findings indicate that some of the abnormal growth in the maxillofacial complex induced by tissue expansion can persist after tissue expander removal.

A limitation of this study is the fact that it provides only two-dimensional information about effects in the midsagittal plane. Three-dimensional data are needed to elucidate the positive and negative effects of tissue expansion.

From this study it can be concluded that tissue expansion of the palatal mucoperiosteum in young growing cats is possible, with

and without scars of the palatal tissues. During growth, however, tissue expansion interferes with the anteroposterior growth of the bony structures at the palatal level. In the vertical direction, the anterior facial and posterior skull heights are altered by tissue expansion. It also interferes with dental development as the incisors become more inferiorly and posteriorly located. This may be due to interference with occlusion and traction in the soft tissues overlying the subperiosteally located tissue expander. Some of these effects, however, seem to be temporary, since there is a relatively accelerated growth at the cranial base after removal of the tissue expander in the scarred tissue expansion group.

Philip A. Van Damme, M.D., D.M.D., Ph.D.
Department of Oral and Maxillofacial Surgery
University Hospital Nijmegen St. Radboud
P.O. Box 9101, 421
6500 HB Nijmegen
The Netherlands

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REFERENCES

1. De Mey, A., Malevez, C., and Lejour, M. Treatment of palatal fistula by expansion. *Br. J. Plast. Surg.* 43: 362, 1990.
2. Abramo, A. C., Viola, J. C., and Angelo, A. J. Intraoperative rapid expansion in cleft palate repair. *Plast. Reconstr. Surg.* 91: 441, 1993.
3. Van Damme, Ph. A., and Freihofer, H. P. M. Palatal mucoperiosteal expansion as an adjunct to palatal fistula repair: Case report and review of the literature. *Cleft Palate Craniofac. J.* 33: 255, 1996.
4. Millard, D. R., Jr. *Cleft Craft: The Evolution of Its Surgery,* Vol. III: *Alveolar and Palatal Deformities.* Boston: Little, Brown, 1980. Pp. 167–262, 809–865.
5. Watson, J. D., Reid, C. D., and Pigott, R. W. The "tadpole flap": Its role in closure of palatal fistulae. *Br. J. Plast. Surg.* 41: 485, 1988.
6. Nakakita, N., Maeda, K., Ando, S., et al. The use of a buccal musculomucosal flap to close palatal fistulae after cleft palate repair. *Br. J. Plast. Surg.* 43: 452, 1990.
7. Egyedi, P. Utilization of the buccal fat pad for closure of oroantral and/or oronasal communications. *J. Maxillofac. Surg.* 5: 241, 1977.
8. Voorsmit, R. A. C. A., and Fennis, J. P. M. The buccal fat pad for closure of oronasal communications in cleft patients. *J. Craniomaxillofac. Surg.* 20(Suppl. 1): 71, 1992.
9. Guerrerosantos, J., and Altamirano, J. T. The use of lingual flaps in repair of fistulas of the hard palate. *Plast. Reconstr. Surg.* 38: 123, 1966.
10. Pigott, R. W., Rieger, F. W., and Moodie, A. F. Tongue flap repair of cleft palate fistulae. *Br. J. Plast. Surg.* 37: 285, 1984.
11. Coghlan, K., O'Regan, B., and Carter, J. Tongue flap repair of oronasal fistulae in cleft palate patients. *J. Craniomaxillofac. Surg.* 17: 255, 1989.
12. Van der Wal, K. G. H., and Mulder, J. W. The temporal muscle flap for closure of large palatal defects in cleft lip and palate patients. *Int. J. Oral Maxillofac. Surg.* 21: 3, 1992.
13. Upton, J., Ferraro, N., Healy, G., et al. The use of prefabricated fascial flaps for lining of the oral and nasal cavities. *Plast. Reconstr. Surg.* 94: 573, 1994.
14. Matsuo, K., Kiyono, M., and Hirose, T. A simple technique for closure of a palatal fistula using a conchal cartilage graft. *Plast. Reconstr. Surg.* 88: 334, 1991.
15. Freihofer, H. P. M., Borstlap, W. A., Kuijpers-Jagtman, A. M., et al. Timing and transplant materials for closure of alveolar clefts: A clinical comparison of 296 cases. *J. Craniomaxillofac. Surg.* 21: 143, 1993.
16. Batchelor, A. G., and Palmer, J. H. A novel method of closing a palatal fistula: The free fascial flap. *Br. J. Plast. Surg.* 43: 359, 1990.
17. Hasegawa, K., Amagasa, T., Araida, T., et al. Oral and maxillofacial reconstruction using the free rectus abdominis myocutaneous flap. *J. Craniomaxillofac. Surg.* 22: 236, 1994.
18. Bardach, J., and Eisbach, K. J. The influence of primary unilateral cleft lip repair on facial growth. *Cleft Palate J.* 14: 88, 1977.
19. Meijer, R., and Prahl, B. Influences of different surgical procedures on growth of dentomaxillary complex in dogs with artificially created cleft palate. *Ann. Plast. Surg.* 1: 460, 1978.
20. Freng, A. The restorative potential of double layered mucoperiosteum: A study on experimental midpalatal clefts in the cat. *Scand. J. Plast. Reconstr. Surg.* 13: 313, 1979.
21. Freng, A. Growth of the middle face in experimental early bony fusion of the vomeropremaxillary, vomeromaxillary and mid-palatal sutural system: A roentgen cephalometric study in the domestic cat. *Scand. J. Plast. Reconstr. Surg.* 15: 117, 1981.
22. Voss, R., and Freng, A. Growth of the dental arches after ablation of the midpalatal suture. *J. Maxillofac. Surg.* 10: 259, 1982.
23. Bardach, J., and Mooney, M. P. The relationship between lip pressure following lip repair and craniofacial growth: An experimental study in beagles. *Plast. Reconstr. Surg.* 73: 554, 1984.
24. Wijdeveld, M. G. M. M., Grupping, E. M., Kuijpers-Jagtman, A. M., and Maltha, J. C. Mucoperiosteal migration after palatal surgery in beagle dogs. *Int. J. Oral Maxillofac. Surg.* 16: 729, 1987.
25. Wijdeveld, M. G. M. M., Grupping, E. M, Kuijpers-Jagtman, A. M., and Maltha, J. C. Growth of the maxilla after soft tissue palatal surgery at different ages in beagle dogs: A longitudinal radiographic study. *J. Oral Maxillofac. Surg.* 48: 204, 1988.
26. Bardach, J., and Kelly, K. M. Does interference with mucoperiosteum and palatal bone affect craniofacial

growth? An experimental study in beagles. *Plast. Reconstr. Surg.* 86: 1093, 1990.
27. Bardach, J., Kelly, K. M., and Salyer, K. E. Relationship between the sequence of lip and palate repair and maxillary growth: An experimental study in beagles. *Plast. Reconstr. Surg.* 93: 269, 1994.
28. Van Damme, Ph. A., Heidbüchel, K. L. W. M., Kuijpers-Jagtman, A. M., et al. Cranio-maxillo-facial tissue expansion, experimentally based or clinically empiric? A review of the literature (Abstract). *J. Craniomaxillofac. Surg.* 20: 61, 1992.
29. Moelleken, B. R. W., Mathes, S. J., Cann, C. E., et al. Long-term effects of tissue expansion on cranial and skeletal bone development in neonatal miniature swine: Clinical findings and histomorphometric correlates. *Plast. Reconstr. Surg.* 86: 825, 1990.
30. Schmelzeisen, R., Schwipper, V., Tilkorn, H., et al. Changes in growth of the facial skeleton following implantation of tissue expanders. *J. Craniomaxillofac. Surg.* 22(Suppl. 1): 81, 1994. (Abstract no. 276).
31. Muller, G.-H. Les applications cliniques de la chimie des silicones. *Ann. Chir. Plast. Esthet.* 38: 660, 1993.
32. LeVier, R. R., Harrison, M. C., Cook, R. R., and Lane, T. H. What is silicone? *Plast. Reconstr. Surg.* 92: 163, 1993.
33. Maltha, J. C. The Process of Tooth Eruption in Beagle Dogs. Ph.D. thesis, Nijmegen, The Netherlands, 1982. P. 46.
34. Eriksen, E., and Solow, B. Linearity of cephalometric digitizers. *Eur. J. Orthod.* 13: 337, 1991.
35. Natsume, N., Miyajima, K., Kinoshita, H., and Kawai, T. Incidence of cleft lip and palate in beagles (Letter). *Plast. Reconstr. Surg.* 93: 439, 1994.
36. Langenbeck, B. Operation der angeborenen totalen Spaltung des harten Gaumens nach einer neuen Methode. *Dtsch. Klin.* 13(24): 231, 1861.
37. Cole, R. P., Gault, D. T., Mayou, B. J., and Davis, P. K. B. Pain and forehead expansion. *Br. J. Plast. Surg.* 44: 41, 1991.
38. Manders, E. K., Schenden, M. J., Furrey, J. A., et al. Soft-tissue expansion: Concepts and complications. *Plast. Reconstr. Surg.* 74: 493, 1984.
39. Antonyshyn, O., Gruss, J. S., Mackinnon, S. E., and Zuker, R. Complications of soft tissue expansion. *Br. J. Plast. Surg.* 41: 239, 1988.